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# PALEOBOTANY.—*Megaspores ascribed to* Selaginellites, *from the Upper Cretaceous coals of Western Greenland.*[1]

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In this paper are described the most outstanding types of megaspores recovered from the samples of Upper Cretaceous Greenland coal, which were collected by Mr. Carl O. Erlanson in 1928. Dr. C. A. Arnold (1) made a preliminary examination and a brief report on these coals, and suggested that a more detailed investigation be undertaken by the writer.

The specimens from which spores were obtained came from two localities, Patoot on the southeast coast of the Nugsuaks Peninsula at an elevation of 165 meters and Skansen on the east coast of Disko Island, two miles inland, at an altitude of 140 meters.

The coal beds of West Greenland range in age, without stratigraphic break, from Lower Cretaceous to Miocene. The coal layers are lenticular, varying in thickness from a few inches to several feet, and are interbedded between sandstone and shale (Ball 2; Bøggild 3, 4). The age of the coal from the localities under consideration appears to be Upper Cretaceous, since Heer (7, 8) recognized the Patoot series as having an Upper Cretaceous flora. White and Schuchert (12) give this series as extending up to about 2,000 feet above sea level. At Skansen, Seward (10), the most recent paleobotanist to study the fossil plant beds of Western Greenland, found Cretaceous strata at a height of 1,900 feet. The collections from Patoot and Skansen were at about 532 and 460 feet respectively, thus bringing these two localities well within the boundaries of the Upper Cretaceous.

[1] Papers from the Department of Botany of the University of Michigan, No. 395. Received August 8, 1932.

## TECHNIQUE

The coal was macerated in bulk by soaking it in dilute nitric acid for a considerable length of time. After this treatment it was washed in water to remove the acid and then placed into a dilute sodium hydroxide solution until the maceration was complete. The resulting brown liquid was washed out and the residue examined under a binocular microscope.

The isolated plant fragments were treated for a short time in hot dilute nitric acid and potassium chlorate followed by hot dilute alkali. This second treatment with the hot acid and alkali helps to clear up and remove any debris adhering to the surface of the specimens. The material was transferred from water to 95% alcohol, and then mounted on a slide in "euparal." This method of mounting in "euparal" is similar to the formalin glycerine-jelly method mentioned by Harris (6) and is as follows:

1. Place the material in 95% alcohol for at least 30 minutes.
2. Transfer the specimens to the slide directly from 95% alcohol.
3. Draw off the 95% alcohol with filter paper or some other absorbent and add several drops of absolute alcohol. Let this stand for about a minute.
4. Draw off only enough absolute alcohol so that the specimens still remain moist and add enough "euparal" to form a thin coating over them.
5. Arrange the specimens on the slide.
6. Set the slide aside until the "euparal" sets sufficiently to hold the objects in place. This can be tested by running the point of a dissecting needle through the "euparal." If it has set, the needle will leave a white streak. The slide should be placed under cover to exclude particles of dust.
7. Add a drop or two more of "euparal" and place the cover glass.

This process makes a good permanent mount in which a large number of small plant fragments can be arranged systematically without having the specimens drift towards the edges of the coverslip as it is applied.

## THE MEGASPORES

The spores are very variable in size but each type defined shows no differences in structure. There appears to be a gradual increase in diameter from the smallest to the largest. Pfeiffer (9) shows that in the genus *Isoetes* the megaspores in general vary between 250 and 900 $\mu$, with a much smaller range in the individual species. Variation

in some species amounts to as much as 310 $\mu$, but the average variation for a species is around 100 $\mu$ or less. In the genus *Selaginella* there also occurs a great difference in the size of the megaspores within a species. Inequality in size of spores because of variation in megaspore number is shown by Duerden (5) to be common in certain species of *Selaginella*, and Van Eseltine (11) finds that very often one megaspore of the tetrad develops at the expense of the other three, which are then very much dwarfed. In a study of the megaspores of *Selaginella*, I also find a great variation of spore size within a species, the largest spores sometimes being twice as large as the smallest ones, with many intergradations.

In *Isoetes* and *Selaginella* the spores formed in tetrahedral groups usually have three commissural ridges (the "triradiate marks") on their inner face. These ridges extend from the apex of the inner face to an equatorial ridge which separates the inner and outer faces. In *Selaginella* a raised equatorial ring is not always present or evident. When megaspores are formed from diads instead of tetrads the commissural ridges are absent. The surface of the spores may be either plain, rugose, spinose, tuberculate or reticulate wholly or in part. The sculpturing and appendages on the surface of the spores provide good diagnostic features.

Since the structures which bore the fossil spores are unknown it is impossible to determine accurately relationships to living plants, but since the markings and structures suggest a very close affinity to the *Selaginellaceae*, it seems very appropriate to place them in the form genus *Selaginellites*. *Selaginellites* was first instituted by Zeiller (13) for specimens from the coal basin of Blanzy, which appeared to differ from *Selaginella* in having more than four megaspores in each megasporangium. Zeiller's distinction does not hold true when considered in the light of the work of Duerden (5) who finds the megaspore number per megasporangium ranging from one to 42 for some species of *Selaginella*. The name *Selaginellites* has been restricted to those species which are known to be heterosporous. The genus *Lycopodites* of Brongniart is used in a more comprehensive sense to include all forms which are not known to be heterosporous, but it seems as though it should be restricted for those homosporous forms that show *Lycopodium* characters. *Selaginellites* as used here includes those fossil forms which have Selaginella-like characteristics, i.e., are heterosporous.

The measurements given for the size of the spores should be interpreted as the range observed in a few clearly conspecific specimens and

not as the absolute limits, which can be established only by the examination of much more material.

**Selaginellites erlansonii** sp. nov.

Body of exine round, 465–1,000 $\mu$ in diameter, the mean being 690 $\mu$; exine reticulate with irregular diaphanous appendages, 17–122 $\mu$ in width, giving the spore a total diameter of 500–1,155 $\mu$ with the mean at 790 $\mu$; no commissural ridges or clefts visible.—Skansen, east coast of Disko Island, Greenland; two miles inland at altitude of 140 meters; Upper Cretaceous. Figures 1–3. This spore is seemingly quite abundant, but fragments of it are recovered more often than perfect specimens. The spores are dark brown or black and very opaque and this may help to account for the apparent lack of the triradiate markings. In Arnold's paper (1) this spore type is shown on Plate III, Figure 2. This species is named in honor of Mr. Carl O. Erlanson, the collector of the coal from which it was recovered, who was botanist on the second Greenland Expedition of the University of Michigan.

**Selaginellites papillosus** sp. nov.

Body of exine round, 648–747 $\mu$ in diameter; triradiate clefts extending about two thirds of the distance to the periphery; exine covered with numerous mamilliform papillae, hemispheric or higher than broad, with apex rounded.—Skansen, east coast of Disko Island, Greenland; two miles inland at altitude of 140 meters; Upper Cretaceous. Figure 9. This spore type was very rare.

**Selaginellites arnoldii** sp. nov.

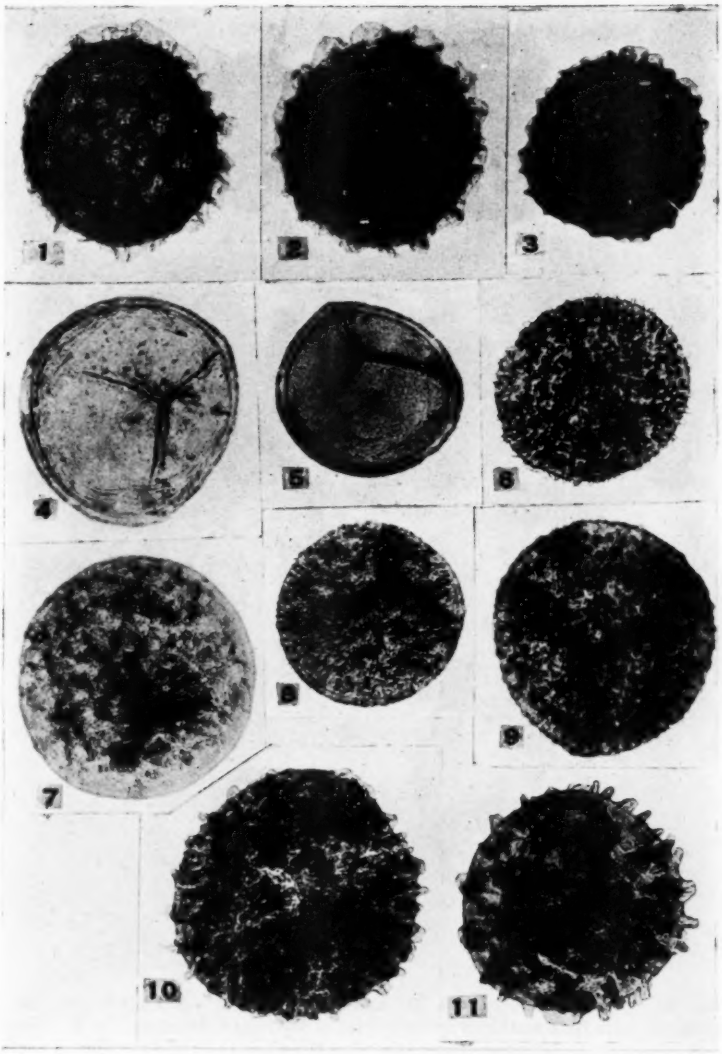
Body of exine round, 465–614 $\mu$ in diameter, average diameter 570 $\mu$; triradiate marks extending over half the distance to periphery; body invested with numerous closely set vermiform papillae, 7–21 $\mu$ wide and 38–70 $\mu$ long, sides parallel, apex rounded.—Skansen, east coast of Disko Island, Greenland; two miles inland at altitude of 140 meters; Upper Cretaceous. Figures 22–25. Patoot, southeast coast of Nugsuaks Peninsula, Greenland, at 165 meters; Upper Cretaceous. This species was rather uncommon but not rare. It is figured by Arnold (1) on Plate IV, Figure 6. The spores are very interesting because of the peculiar appendages which invest the exine. The triradiate markings appear as fine lines.

**Selaginellites greenlandicus** sp. nov.

Body of exine round, 515–698 $\mu$ in diameter, the mean about 595 $\mu$; triradiate clefts reaching half to two-thirds of the distance to the periphery; covered with finger-like appendages, 17–28 $\mu$ wide and 17–44 $\mu$ long, with sides nearly parallel, and apex rounded or blunt, usually somewhat distantly set.—Skansen, east coast of Disko Island, Greenland; two miles inland at altitude of 140 meters; Upper Cretaceous. Figures 10, 11. This spore was about equal in abundance to *S. arnoldii*.

**Selaginellites echinatus** sp. nov.

Body of exine round, 349–400 $\mu$ in diameter; triradiate clefts extending about two thirds of the distance to the periphery; exine covered with echinate appendages, tapering to an acute point, straight or somewhat curved.—Skansen, east coast of Disko Island, Greenland; two miles inland at altitude of 140 meters; Upper Cretaceous. Figure 6. This form was as rare in the coal as *S. papillosus*.




Figs. 1, 2.—*Selaginellites erlansonii*. Large specimens showing the reticulations with the irregular diaphanous appendages. × 36. Fig. 3.—*S. erlansonii*. A small specimen showing the reticulations with a less conspicuous irregular diaphanous appendage. × 60. Figs. 4, 5.—*S. rotundus*. This shows the range in size of the spores, with the well defined triradiate markings and thick exine. × 60. Fig. 6.—*S. echinatus*. A perfect specimen, with the triradiate markings. × 60. Figs. 7, 8.—*S. inornatus*. A large and an average sized spore showing the triradiate marks. × 60. Fig. 9.—*S. papillosus*. An excellent specimen showing the triradiate markings. × 60. Figs. 10, 11.—*S. greenlandicus*. Large specimens showing the characteristic appendages and the triradiate markings. × 60.

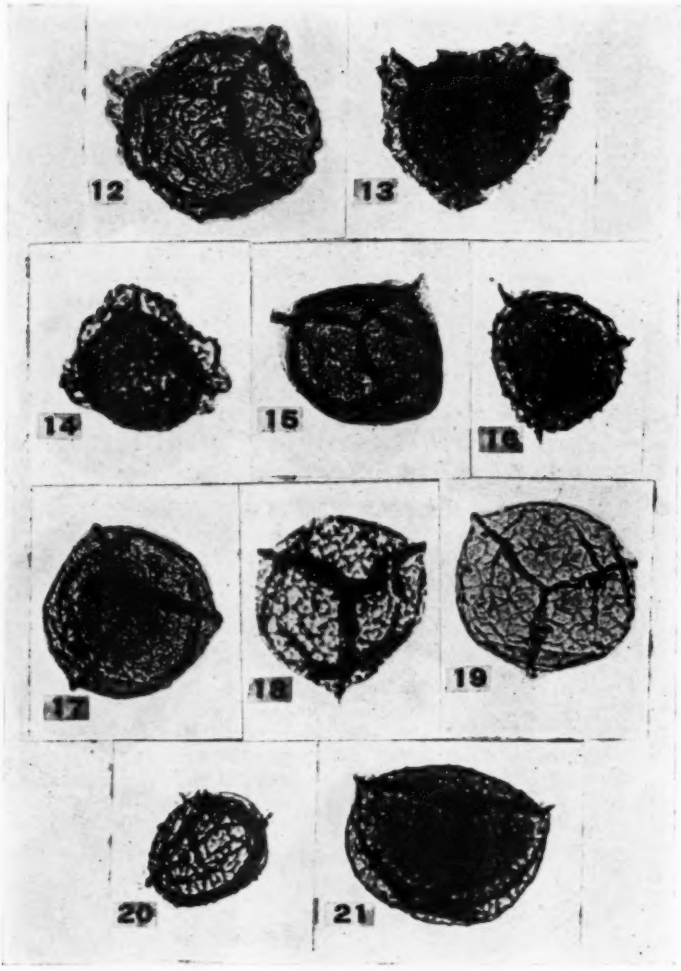
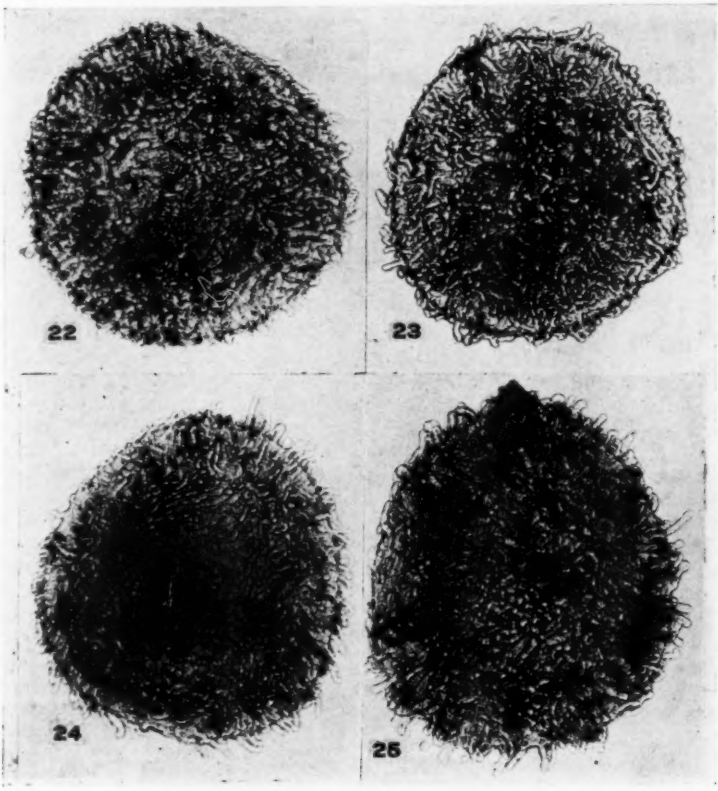



Fig. 12.—*Selaginellites borealis.* A small spore in a very wrinkled condition, but showing the triradiate markings and a portion of the equatorial wing. × 96. Figs. 13, 14.—*S. borealis.* Excellent specimens showing the spore body and the almost complete equatorial wing. × 66. Fig. 15.—*S. borealis.* A somewhat wrinkled specimen showing the extent of the triradiate marks and a portion of the wing. × 66. Fig. 16—*S. borealis.* A specimen with the wing missing, but showing the triradiate marks extending beyond the periphery of the spore body. × 66. Figs. 17, 18.—*S. borealis.* Specimens showing only a small portion of the equatorial wing on the radii of the triradiate marks. × 66. Fig. 19.—*S. borealis.* A specimen consisting of only the inner face of a spore, showing the triradiate markings and the inconspicuous reticulations. × 66. Fig. 20.—*S. borealis.* A somewhat wrinkled specimen, from which the equatorial wing has been broken, showing only the spore body. × 66. Fig. 21.—*S. borealis.* A specimen somewhat flattened laterally showing the triradiate markings extending a little beyond the periphery of the spore. × 66.

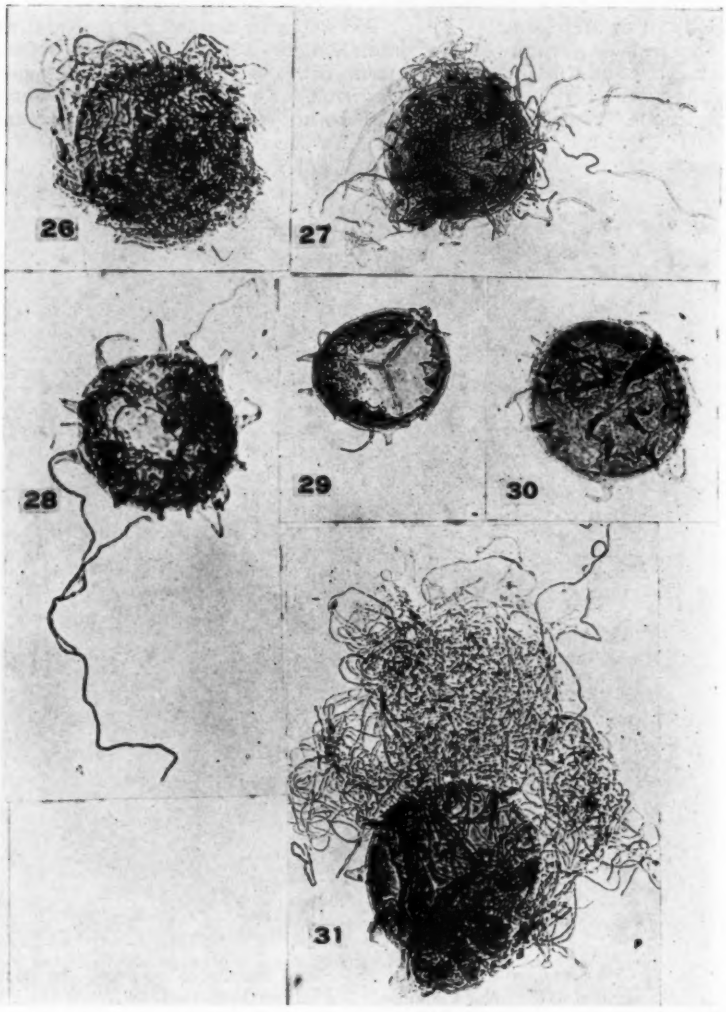
**Selaginellites borealis** sp. nov.

Body of exine practically round, 265–350 $\mu$ in diameter; equatorial wing 50–83 $\mu$ wide on the radii of the triradiate markings, and 16–50 $\mu$ in between, making the total diameter of the spore 332–480 $\mu$; triradiate markings extending to the periphery of the wing; irregular reticulations present but not conspicuous.—Skansen, east coast of Disko Island, Greenland; two miles




Figs. 22–25.—*Selaginellites arnoldii*. Excellent specimens showing the peculiar vermiform papillae which cover the spore. The triradiate marks show as fine black lines in Figs. 22, 23. × 110.

inland at altitude of 140 meters; Upper Cretaceous. Figures 13–21. Patoot, south coast of the Nugsuaks Peninsula, at altitude of 165 meters, Greenland; Upper Cretaceous. Figure 12. This spore type is figured by Arnold (1) on Plate IV, Figure 1. It was more abundant in the coal from Skansen, than in that from Patoot. The exine of this species seems to be quite thin and delicate as in many instances the spores are very wrinkled and the wing is broken or missing.




Figs. 26, 27, 31.—*Selaginellites ariadnae*. Specimens showing the tangled and matted condition of the thread-like appendages. × 97. Fig. 28.—*S. ariadnae*. A spore from which part of the appendages were removed so as to show the long thin appendages, with the broader funnel-form base. × 97. Fig. 29.—*S. ariadnae*. A specimen from which the appendages and a portion of the wall were removed so as to show the triradiate clefts. × 97. Fig. 30.—*S. ariadnae*. A view of the outer face of a spore showing the distribution, arrangement, and attachment of the appendages. × 97.

**Selaginellites inornatus** sp. nov.

Body of exine round, 200–664 $\mu$ in diameter, the mean being 440 $\mu$; exine smooth, 5–18 $\mu$ thick; triradiate clefts extending a third to a half of the distance to the periphery, clefts slightly margined.—Skansen, east coast of Disko Island, Greenland; two miles inland at altitude of 140 meters; Upper Cretaceous. Figures 7, 8. This spore was the next most abundant *Selaginellites*, but was found generally in a broken or damaged condition.

**Selaginellites subrotundus** sp. nov.

Body of exine rounded-subdeltoid, 432–698 $\mu$ in diameter, the average being near 506 $\mu$; exine 30–40 $\mu$ thick; triradiate clefts with somewhat thickened margins, extending two thirds or more of the distance to the periphery; exine smooth.—Skansen, east coast of Disko Island, Greenland; two miles inland at altitude of 140 meters; Upper Cretaceous. Figures 4, 5. Although not as abundant as *S. inornatus* this spore was generally recovered in excellent condition. This may be because of its very thick exine. It resembles the former species very much, but differs in the thicker exine, larger size, and more deltoid shape.

**Selaginellites ariadnae** sp. nov.

Body of exine round, 150–316 $\mu$ in diameter, the mean being 233 $\mu$; triradiate clefts extending over half the distance to the periphery; body invested with 8–15 thread-like appendages, 3–4 $\mu$ in width, few to several times the diameter of the spore in length, base broad and funnel-form, apex blunt or rounded.—Skansen, east coast of Disko Island, Greenland; two miles inland at altitude of 140 meters; Upper Cretaceous. Figures 26–31. This is the predominating spore type recovered from the coal. It is usually entangled by the thread-like appendages, which sometimes completely hide the spore. It is only after untangling and straightening out the appendages that the real structure of the spore can be seen. The number of visible appendages depends upon the plane in which the spore was flattened, the fewest number being on the inner face of the spore.

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## PALEONTOLOGY.—Antillophyllia, *a new coral generic name.*[1]

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The genus *Antillophyllia* may be defined as follows:

Corallum simple, turbinate, compressed turbinate, bilobate, or sub-cornute in form; attached at least in the earliest stages, pedicel minute or moderately large. Externally invested by a more or less complete, detachable epitheca. Costae distinct, moderately prominent, subequal or equal in size, margins with very regular, usually transversely compressed dentations. Septa numerous, with minutely dentate margins, the dentations frequently (if not always) papilliform in character. Margins of the larger septa divided by a sinus into an inner and outer lobe, the inner very narrow in the constricted portion of bilobate calices. Septal faces with fine opposed striations, along whose courses are granulations. The striations are finer on the inner than on the outer septal lobe. Columella not greatly developed, compressed in the plane of the greater diameter of the calice, vesicular. Dissepimental endotheca very abundant; exotheca frequently well developed, sometimes forming a wall outside of an inner wall which originates by the thickening of the sides of the septa.

*Type species.*—*Antillia lonsdaleia* Duncan from the Miocene of the Dominican Republic.

P. Martin Duncan (1864, p. 28) proposed the name *Antillia* and included in it four species, viz., *Montlivaltia ponderosa* Duncan (not Milne Edwards and Haime), *Antillia dentata* Duncan, *A. lonsdaleia* Duncan, and *A. bilobata* Duncan. He later added another species, *A. walli* (Duncan and Wall, 1865, p. 11). These five species represent two systematic groups of corals, one of which has coarsely dentate septal margins, contains the species wrongly identified as *Montlivaultia ponderosa* M. Edw. and Haime and *Antillia dentata* Duncan. It is related to the mussoid corals. The other group has septa with finely dentate margins and to it belong *A. lonsdaleia*, *A. bilobata*, and *A. walli*, all described by Duncan.

There was confusion at the start. Not only did Duncan include two different genera under *Antillia* when he first proposed the name, but he made a double misidentification of species. Comparison of photographs of the type of *Montlivaultia ponderosa* M. Edwards and Haime kindly sent me from the Museum of Natural History in

[1] Received August 16, 1932.

Paris shows that Duncan's *Montlivaltia ponderosa* from the Miocene of Bowden, Jamaica, is not *Montlivaultia ponderosa* Milne Edwards and Haime. I undertook to correct this error by naming the Bowden, Jamaica, species *Antillia gregorii* (Vaughan, 1901, p. 6). The specimens from the "Nivajé Shale," Dominican Republic, identified by Duncan as "*Antillia ponderosa*" is, as shown by an examination of the specimen studied by Duncan, not the same species as the Bowden "*Antillia ponderosa*," but is Duncan's *Antillia dentata* from the Dominican Republic. Duncan's *Antillia ponderosa*, therefore, included two species, neither one of which was *Montlivaultia ponderosa* M. Edwards and Haime.

J. W. Gregory (1895, p. 266) wrote as follows:

"The inclusion in the list of synonyms of a species which Duncan assigned to *Antillia* renders necessary a remark on this genus, and on the value of the epitheca in this group. The genus was founded by Duncan in 1864; he included in it a series of species agreeing in having an essential columella and a membraniform epitheca. The septa and costae are of two types: in some species, as in his type-species *A. ponderosa*, the septa are not lobed and the costae are coarsely dentate; in other species, such as *A lonsdaleia*, the septa are lobed and the costae finely granulate. In his 'Revision' (p. 60) he reduces the genus to a subgenus of *Circophyllia*, and still bases its value on the epitheca.

The examination of a considerable series of specimens shows, however, that the epitheca is so very variable in this group that it does not appear worthy of even subgeneric value; the characters of the septa and costae seem much more important. In some specimens the epitheca is present and in others, quite rudimentary, and all stages can be seen between the two conditions. In this case the genus has to be split up into two. Duncan's type goes into *Lithophyllia*, and the *A. lonsdaleia* and some others go into *Circophyllia*."

In 1901 I wrote (Vaughan, 1901, p. 6):

"I am not sure that these two species (*Lithophyllia lacera* (Pallas) and *L. cubensis* (M. Edw. & H.) are really distinct; however, I am sure that *Antillia ponderosa* Duncan (*non*-Milne Edwards and Haime) is a distinct species and does not belong in the synonymy of *L. cubensis*. As Duncan wrongly identified the species with Milne Edwards and Haime's *Montlivaultia ponderosa*, it has no name. Therefore I propose to call it *Antillia gregorii*, nom. nov."

The type species of *Antillia* is *Antillia gregorii* Vaughan, which is, as has been stated, Duncan's *Antillia ponderosa*, not *Montlivaultia ponderosa* Milne Edwards and Haime.

Reuss (1860, p. 216, pl. 1, figs. 10–12, pl. 2, fig. 10) described the genus *Syzygophyllia* from the eastern Hungarian Miocene. The type species is *S. brevis* Reuss (Vaughan, 1919, p. 424). *Antillia* Duncan, 1864, is a synonym of *Syzygophyllia* Reuss, 1860.

A few notes will be made on *Circophyllia*. Filliozat (1914, pp. 96-97) has said:

> "Grace à la grande complaisance de M. le Professeur Joubin, j'ai eu depuis l'occasion d'examiner attentivement au Muséum les échantillons de *Circophyllia truncata* de la collection Milne Edwards. Je puis alors constater que la diagnose des auteurs présentait des lacunes de la plus haute importance et que mes spécimens de la ferme des Boves, à Parnes, dècrits sous le nom de *Felixopsammia arcuata* [Filliozat, 1910, p. 804, pl. 14, figs. 7–11] devaient etre identifiés à *Circophyllia truncata* E. H."

From Filliozat's restudy of the type-species of *Circophyllia*, it is evident that none of the corals placed in *Antillia* by Duncan can be referred to *Circophyllia*, which is an Eupsammid genus. Duncan's *Antillia lonsdaleia*, *A. bilobata*, and *A. walti* are, therefore, without a proper generic designation.

I must now confess my own sins. Notwithstanding that it was known to me that the name *Antillia* was invalid, I applied it to species of corals as follows: *Antillia dubia* (Duncan) and *A. bilobata* Duncan (Vaughan, 1921, p. 115), *A. bilobata* Duncan (*idem*, p. 127), *A. dominicensis* Vaughan (*idem*, p. 152), *A. bilobata* Duncan and *A. walli* Duncan (*idem*, p. 157), *Antillia dominicensis* Vaughan (Vaughan and Hoffmeister, 1925, p. 324, pl. 3, fig. 9, pl. 4, figs. 1, 2, which are upside down), and *A. sawkinsi* Vaughan (Vaughan and Hoffmeister, 1926, p. 118, pl. 2, figs. 6, 6a).

I should accept responsibility for the misuse of the name by Hoffmeister (Vaughan and Hoffmeister, 1926, p. 119, pl. 2, figs. 7, 7a, 8, 8a) in his *Antillia bullbrooki* and by Faustino (1927, p. 152, pl. 37, figs. 2, 3) in his designation of *Antillia constricta* Brueg. *A. constricta* does not belong to the mussoid corals.

It is also probable that I misled Yabe and Sugiyama in their use of the name *Antillia*.

I shall not undertake a complete revision of the species that have been confused under *Antillia*, but I shall list the American species, the generic identification of which seems certain, and comments will be made on a few other species.

The species which belong to *Antillia* as represented by the type-species, but which are now referred to *Syzygophyllia*, because that is the older name, are as follows:

*Syzygophyllia gregorii* (Vaughan)
*dentata* (Duncan)
*hayesi* (Vaughan)

The American Miocene species which have been referred to *Antillia* and which are now placed in the genus *Antillophyllia* are as follows:

*Antillophyllia lonsdaleia* (Duncan) genotype
*bilobata* (Duncan)
*walli* (Duncan)
*dubia* (Duncan) (described as Flabellum)
*dominicensis* (Vaughan)
*sawkinsi* (Vaughan)
*bullbrooki* (Hoffmeister)
*ponderosa* (M. Edw. and H.)

I am in doubt regarding *Antillia explanata* Pourtalès, a Recent Barbadian species.

A few Indo-Pacific living species which obviously belong to *Antillophyllia* are *A. geoffroyi* (Audouin), *A. constricta* (Brueg.), *A. sinuata* (Gardiner), and *A. flabelliformis* (Yabe and Sugiyama).

Yabe and Sugiyama (1931) repeated Duncan's error in their treatment of *Antillia*, but I have already stated that I may be at least partly to blame for their confusion. *A. constricta* Brueg. and *A. flabelliformis* Yabe and Sugiyama clearly belong to *Antillophyllia*, and *A. duncani* Yabe and Sugiyama probably does. But *Antillia japonica* Yabe and Sugiyama and *A. nomaensis* Yabe and Sugiyama are mussoid corals and do not belong to the same genus as the other species. The last mentioned two species do not appear to be referable to *Syzygophyllia* but look as if they probably represent the young stages of one or more species of mussoid corals which are compound in the adult stages.

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## PALEONTOLOGY.—*A new species of* Lepidocyclina *from the Panama Canal Zone.*[1]

THOMAS WAYLAND VAUGHAN, Scripps Institution of Oceanography, and W. STORRS COLE, Ohio State University.

The species described below was picked out of material collected by Prof. R. W. Chaney for the senior author in the Panama Canal Zone, at a locality formerly known as Bohio Ridge Switch. The locality is the same as no. 6025 of the Vaughan and MacDonald collections made in 1911 (See MacDonald, 1919, p. 540, and pl. 154).

**Lepidocyclina (Lepidocyclina) pancanalis** Vaughan and Cole, n. sp.
Figs. 1–9.

Test small, lenticular, relatively inflated, slope from central area to margin nearly uniform, without or with a very narrow marginal flange. Outline in plan subcircular or faintly polygonal. One vaguely hexagonal specimen has obscure radii at the edge (Fig. 6). The ornamentation is of two intergrading kinds. On some specimens there are over the center of the test small papillae which are about 130 $\mu$ in diameter, as shown on Figures 1–4, 6. On other specimens the papillae are larger and tend to fuse. The latter kind of ornamentation grades into costulation of the apex, such as is represented by Figure 5. Although four flattish costae, with intervening depressed areas, are shown on the apex of this specimen, the costulation is indefinite. A specimen not figured has an apical, central, coarse papilla, with smaller papillae and faint costules around it. Over the centers of some specimens, Figs. 1 and 2, there are slight depressions. It seems that no two specimens are exactly alike. The foregoing notes are based on seven specimens, six of which are figured.

The diameter of megalospheric specimens ranges from 1.5 to 2.0 mm. and the thickness through the center ranges from 0.75 to 1.0 mm. Ratio of diameter to thickness, about two to one.

There are two subequal, small, embryonic chambers which are divided by a straight wall. The length of the two chambers is about 185 $\mu$; width, about 145 $\mu$; thickness of wall, about 25 $\mu$.

The equatorial chambers are of three intergrading kinds. Most of the chambers have curved outer and converging inner walls; some of them are

[1] Received August 16, 1932.

diamond shaped; those nearest the periphery are nearly hexagonal or of short spatulate form. The chambers near the center have a transverse diameter of 35 to 45 $\mu$ and a radial diameter of 30 to 40 $\mu$; those near the periphery have a transverse diameter of about 50 $\mu$ and a radial diameter of about 60 $\mu$. Near the center the height is about 30 $\mu$. The height increases very gradually toward the periphery where it is about 55 $\mu$. The chambers are connected by stolons, the openings for which are about 7 $\mu$ in diameter. They are shown in the vertical illustrated by Figure 8.

The lateral chambers form regular tiers. There are about 10 in a tier on each side of the equatorial layer over the center. Outward, the number in a tier regularly decreases toward the periphery where there is only one layer on each side of the equatorial layer. Just over the embryonic apparatus the height is about 20 $\mu$ and the length about 40 $\mu$. There is increase in size outward until at the periphery over the central area the height is about 40 $\mu$ and the length about 60 $\mu$. A few relatively strong pillars are developed between the tiers over the center of the test.

The species to which *L. pancanalis* is most nearly related is *L. canellei* Lemoine and R. Douvillé. *L. canellei* is usually larger, but the senior author has specimens of a dwarf variety from Arbol Grande, near Tampico, Mexico. In *L. canellei* the ratio of the diameter to thickness is greater, and in perfectly preserved specimens there is a distinct flange which may be peripherally thickened. *L. canellei* lacks the pillars and the thickened surface papillae and costulations of *L. pancanalis*. The equatorial chambers of *L. canellei* are strikingly regular hexagonal in shape, while those of *L. pancanalis* are dominantly of diamond or short-spatulate form.

*Co-types and topo-types.* The specimens on which the foregoing description is based and which are here illustrated, have been donated to the U. S. National Museum. Topotypes, Scripps Institution of Oceanography.

*Geologic relations and associated species.* The locality at which the type-specimens were collected has already been stated. The geologic horizon is given by MacDonald as the upper part of the Culebra formation, but actually the stratigraphic relations of the bed from which the specimens were collected is not certainly known. The senior author surmises that the bed does not belong within, but lies below the Culebra formation.

Associated with *L. pancanalis* at its type locality are other organisms as follows (see Vaughan, 1919*b*, pp. 550–554; 1924, pp. 787, 802):

*Camerina panamensis* (Cushman)

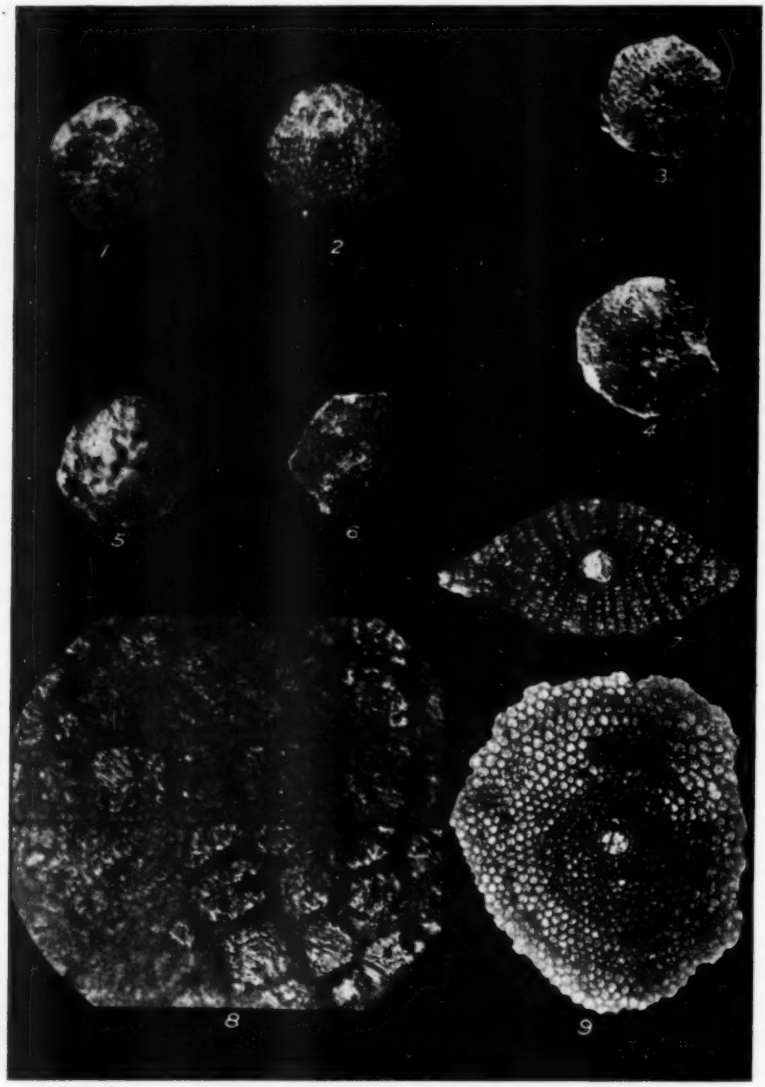
*Heterostegina* n. sp. (described in a ms. by D. W. Gravell)

*Miogypsina* (*Miolepidocyclina*) *panamensis* (Cushman)

*Lepidocyclina* sp., erroneously identified by Cushman as *L. chaperi*.

In Antigua, *L. pancanalis* has been found in collections made by W. R. Forrest at Cocoanut Hall, in the upper stratified beds at Half Moon Bay, and at southeast point, Long Island. Commonly, associated with *L. pancanalis* at these localities are:

*Lepidocyclina parvula* Cushman
*undosa* Cushman
*vaughani* Cushman




*Lepidocyclina* (*Lepidocyclina*) *pancanalis* Vaughan and Cole, n.sp.

Figs. 1-6.—Surface views, × 12, of six specimens.

Fig. 7.—Vertical section, × 28.

Fig. 8.—A part of a vertical section, × 200, to show the stoloniferous apertures in the walls of the equatorial chambers. Three pairs of the apertures are represented by the pairs of white dots.

Fig. 9.—Equatorial section, × 28, to show the embryonic and equatorial chambers.

The horizon in Antigua is in the Antigua formation, but it may be considerably above the base of the formation.

Collateral information on the probable correlation of the Panama exposure above discussed may be obtained by comparing it with the exposure at locality 6024 of MacDonald's report (1919, p. 540). The two are very near together. At this locality the following species were collected:

In the lower 10 ft. *Camerina panamensis* (Cushman)
*Miogypsina* (*Miolepidocyclina*) *panamensis* (Cushman)

In the upper 10 ft. *Stylophora imperatoris* Vaughan[2]
*macdonaldi* Vaughan[2]
*Acropora panamensis* Vaughan[3]
*saludensis* Vaughan[3]

There are two other groups of facts that bear on the stratigraphic position of the exposure at locality 6025. The first of them is that at MacDonald's locality 6026 (1929, p. 541) there is an Antiguan middle Oligocene coral fauna. A species of *Camerina* was doubtfully identified as *C. panamensis*. In the Panama Canal Zone *L. canellei* and *L. vaughani* occur in association (Vaughan, 1923, pp. 254, 255), but in Antigua, *L. vaughani* occurs in association with *L. pancanalis*. Specimens previously reported by the senior author as *L. canellei* from Half Moon Bay, have proved in detailed study to be *L. pancanalis*. The second group of facts is that *Miogypsina cushmani* occurs in the vicinity of Culebra in both the upper part of the Culebra formation and in the immediately overlying Emperador limestone.

Notwithstanding lack of the desired definiteness in the information given above, the indications are that the stratigraphic position of the bed exposed at locality 6025 is about the same as the beds exposed at Half Moon Bay, Antigua, but below the horizon of *Miogypsina cushmani* in the upper part of the Culebra formation as that formation was exposed in Gaillard Cut before water was let into the Panama Canal. As the beds at Half Moon Bay occur within the Antigua formation, but apparently not in its basal part, the stratigraphic position of the bed exposed at locality 6025 in Panama is Oligocene, perhaps upper rather than middle. The European age equivalent is probably Chattian.

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[2] Also in the Emperador limestone which overlies the Culebra formation.

[3] Also in the middle Oligocene, Antigua formation at Rifle Butts, Antigua (see Vaughan, 1919*a*, pp. 201, 208, 209).

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## ENTOMOLOGY.—*A new species of* Rhodnius *from Panama (Hemiptera: Reduviidae).*[1]

H. G. BARBER, Bureau of Entomology. (Communicated by HAROLD MORRISON.)

**Rhodnius pallescens** n. sp.

*Color:* Pale testaceous, dull, marked with fuscous. Head beneath and laterally, before the eyes, and a narrow longitudinal stripe behind the eyes on a line with the ocelli, fuscous; a conspicuous, narrow, median, longitudinal, pale testaceous line running from extreme apex to base of head, somewhat widened between the eyes. Antennae with the first segment, a little over basal half of second, and most of the fourth, except at extreme base and apex, pale testaceous, often faintly mottled with fuscous; the remainder infuscated. Rostrum sordid testaceous, faintly mottled with brown. Pronotum conspicuously marked with pale testaceous on a fuscous background; lateral margins and two longitudinal carinae, one on either side of the middle, very plainly calloused, pale testaceous; the anterior lobe between the two median carinae with two elongate, oval, unbroken fuscous spots, anteriorly narrowed and not attaining the depressed anterior margin; just within the anterior angles a small, subtriangular, fuscous spot, behind which is a broken fascia, of the same color, occupying the space on each side between the lateral margin and the median carina; posterior lobe granulose, with many pale testaceous pustules on a fuscous background; a median, longitudinal, testaceous, slightly calloused, granulated stripe between the two median carinae, and a broader, more irregular, non-calloused fascia on each side between the lateral margin and the median carina. Scutellum pale testaceous, disk with three distinctly excavated fuscous spots basally, the median one frequently immaculate, the inclined sides infuscated to beyond the middle. Hemielytra with the surface for the most part pale testaceous, with the veins concolorous; median or inner field of the corium with a conspicuous, broad, slightly curved, fuscous stripe; a much narrower and less conspicuous stripe contiguous to and paralleling the submedian nervure; sometimes also the claval suture anteriorly, and extreme apex of corium, infuscated. The membrane pale, sordid testaceous, with the outer long cell, except along the limiting veins, faintly embrowned, with pale irrorations through the center, the inner long cell very slightly embrowned before the middle; the surface posterior to the long cells frequently irrorated or tinted with brown. The connexivum pale testaceous, each segment anteriorly at the lateral margin with an elongate, rectangular fascia, over twice as wide as long and narrowly separated from a more elongate narrower stripe, partially concealed by the margin of the corium. Pleura fuscous, granulose, broadly and irregularly striped, and mottled with testaceous. Venter embrowned, with two or three longitudinal series of irregular

[1] Received August 15, 1932.

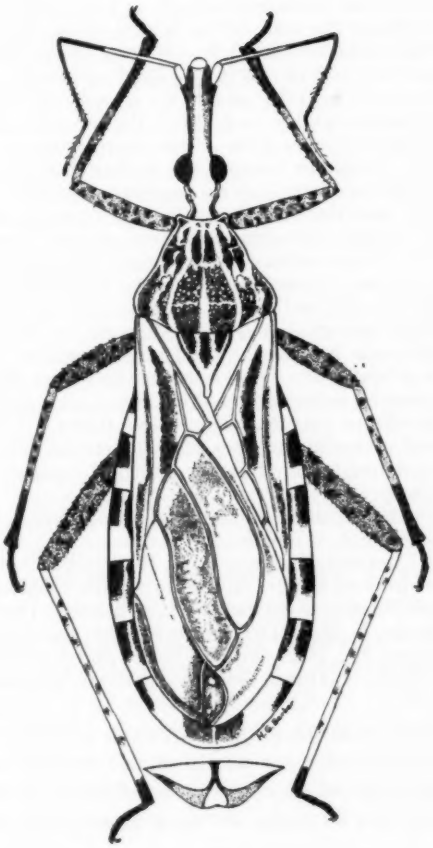

Fig. 1.—*Rhodnius pallescens* n. sp.

pale testaceous spots on either side toward the lateral margins. Legs pale testaceous, mottled with brown, the tibiae apically and the tarsi embrowned.

Head laterally finely and densely granulose; 4.64 mm. long and 1.6 mm. wide across the eyes; space between the eyes slightly longer than the diameter of an eye (0.56 mm. to 0.52 mm.); distance from eye to apex of antenniferous tubercle (lateral view) $2\frac{2}{3}$ to $2\frac{1}{2}$ times as long as from the apex of the latter to the front of the clypeus; antennae as long as head and pronotum together; basal segment attaining the apex of the lateral lobes; second segment about seven times as long as first; the relative lengths of the segments as follows: I 0.48, II 3.20, III 2.40, and IV 1.60 mm.; third and fourth segments sparsely pilose. Rostrum reaching very nearly to margin of anterior acetabulae; first and third segments equal to each other, the second segment 4 to $4\frac{1}{2}$ times as long as either of the other two. Pronotum distinctly wider than long (4 mm. to 3.04 mm.); anterior lobe, on the median dorsal line, 1.04 mm. long, the posterior lobe 2 mm. long; lateral margins distinctly concavely sinuate between the lobes; anterior angles prominent, forming somewhat rounded lobes anteriorly; lateral margins and two median longitudinal carinae strongly calloused; dorsal surface of posterior lobe elsewhere covered with conspicuous small, pale, testaceous pustules. Scutellum longer than wide (2 mm. to 1.76 mm.), disk with three strongly excavated longitudinal areas basally, the median one attaining the middle of the scutellum; contracted apical part transversely furrowed, cylindrical, somewhat elevated. Hemielytra not quite reaching apex of abdomen; entire length from base of corium to apex of membrane 12 mm.; corium along costal margin 8 mm. long; length of inner cell of membrane 5.6 mm., of outer cell 6 mm. Length of body from posterior margin of pronotum to apex of abdomen 12.16 mm. Connexivum broadly exposed; diameter of abdomen at third segment 5.6 mm. Pleura granulose, pustulate.

Length of male 19.84 mm., diameter of pronotum 4 mm., diameter of abdomen 5.6 mm.; length of female, 21–32 mm.

Type male: La Chorrera, Panama, V, 12, 1912 (collected by August Busck). Paratypes, males: four with same data as type; one Trinidad River, Panama, V, 8, 1911 (August Busck); females: one La Chorrera, Panama, V, 10, 1912; one Cabima, Panama, V, 28, 1911 (August Busck); one Close's, Cano Saddle, Canal Zone, Panama, IX, 1923 (M. F. Close); and two Ancon, Canal Zone, Panama, VII, 1932 (L. H. Dunn, Gorgas Memorial Laboratory). U.S.N.M. Cat. No. 44329.

There is very little variation in the series of eleven specimens at hand from Panama. *Rhodnius pallescens* is closely related to both *prolixius* Stål and *pictipes* Stål, from either of which it differs especially in its paler coloration and relative proportion of parts, having a longer and narrower head and pronotum.

The lower part of Figure 1 shows the posterior view of the genitalia.

### Key to Three Species of Rhodnius

1. First, second, and base of third segment of antenna and legs uniformly pale chestnut-brown, not mottled or banded with fuscous. Disk of scutellum with a single basal excavation. Dimensions of parts of male as follows: head 4.16 mm. long, 1.74 mm. wide across eyes; apex of head to eyes 2.4 mm.; dorsal diameter of eye 0.56 mm.; vertex between eyes 0.62 mm.; second segment of rostrum $3\frac{1}{2}$ times

as long as basal; pronotum 2.96 mm. long, 4 mm. wide, anterior lobe 1.04 mm. and posterior lobe 1.92 mm. long; scutellum 1.68 mm. long, 1.6 mm. wide; length of body from posterior margin of pronotum to apex of abdomen 11.04 mm., diameter at third segment 5.2 mm. **prolixius** Stål.

First two segments of the antenna not unicolorous; legs mottled with brown and the tibiae sometimes banded with fuscous. Disk of the scutellum with three excavations..... 2

2. Antenna with basal segment, apical part of second, and base of third and fourth segments infuscated; tibiae with two fuscous bands, one median and one apical. Fuscous spots on segments of connexivum posteriorly forked. Dimensions of parts of male as follows: head 4.56 mm. long, 1.68 mm. wide across eyes; apex of head to eyes 2.54 mm., dorsal diameter of eye 0.6 mm., vertex between eyes 0.48 mm.; pronotum 3.36 mm. long, 4.16 mm. wide, anterior lobe 1.2 mm., posterior lobe 2.16 mm. long; scutellum 2.08 mm. long, 1.8 mm. wide; length of body from posterior margin of pronotum to apex of abdomen 11.28 mm.; diameter at third segment 5.44 mm..... **pictipes** Stål.

Antenna with apex of second, all of third, and sometimes narrow base and apex of fourth segment infuscated. Legs pale testaceous, mottled with brown; tibiae without a median fuscous band but infuscated at apices. Elongate rectangular spots on segments of connexivum not posteriorly forked. Dimensions of parts of male as follows: head 4.64 mm. long, 1.6 mm. wide across eyes; apex of head to eyes 2.8 mm.; dorsal diameter of eye 0.52 mm., vertex between eyes 0.56 mm.; pronotum 3.04 mm. long, 4 mm. wide, anterior lobe 1.04 mm., posterior lobe 2 mm. long; scutellum 2 mm. long, 1.76 mm. wide; length of body from posterior margin of pronotum to apex of abdomen 12.16 mm.; diameter at third segment 5.6 mm.... **pallescens** n. sp.

ZOOLOGY.—*Annotations on the nomenclature of some plant parasitic nematodes.*[1] G. STEINER, Bureau of Plant Industry.

In a recent paper (Steiner 1931) attention was called to the fact that the genus *Aphelenchus*, as previously conceived, contained through error, some species not possibly belonging to it. The proposition was therein made to raise to generic rank the group for which Cobb, 1927, had created the subgeneric term, *Pathoaphelenchus*.

In 1894, however, Fischer described under the name of *Aphelenchoides kühnii* (Fischer speaks of a subgenus but later in his paper places "nov. gen. et nov. spec." after the name) a form which in our judgment is *Aphelenchus parietinus* of Bastian, 1865, and which in turn is the type of *Pathoaphelenchus*. *Aphelenchoides* Fischer 1894, antedates *Pathoaphelenchus* Cobb 1927, and therefore replaces it, with *Aphelenchoides parietinus* (Bastian) Fischer 1894 as type. Synonyms of this type species are *Aphelenchus modestus* de Man 1876, *Tylenchus gracilis* Cobb 1888 (=*Aphelenchus gracilis* Cobb 1891, =

[1] Received July 19, 1932.

*Tylenchus cobbi* de Man 1906), *Aphelenchus ormerodis* Ritzema Bos 1891, and *Aphelenchoides kühnii* Fischer 1894.

It may further be noted that *Tylenchus gulosus* Kühn 1889 and Fischer 1894, is a synonym of *Tylenchus pratensis* de Man 1884. This adds the following plants to the list of hosts of *T. pratensis: Beta vulgaris* var. *rapa, Brassica campestris, Linum usitatissimum, Pisum sativum, Vicia villosa, Clematis jackmani,* and *Hepatica triloba.*

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# PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

## PHILOSOPHICAL SOCIETY

### 1030TH MEETING

The 1030th meeting was held in the Cosmos Club Auditorium, Saturday evening, December 19, 1931. The meeting was called to order at 8:15 P.M. by President TUCKERMAN.

*Program:* E. O. HULBURT: *The temperature of the lower atmosphere.*—From the known amounts of the various gases of the atmosphere from sea-level to about 20 km, from the observed light-absorption coefficients of the gases and from the albedo of the Earth's surface, the temperature of the atmosphere in radiative equilibrium is calculated on the assumption that the sunlight is the only source of energy. The sea-level temperature comes out to be about 19° above the observed world-wide average value 287°K, and the temperature above about 3 km falls many degrees below the observed temperatures. The temperature gradient in levels from 3 to 6 km is greater than that of convective equilibrium and hence the atmosphere would not be dynamically stable if radiation equilibrium prevailed. Therefore air-currents take place to bring about convective equilibrium. Continuing the calculation it is found that only when the convective region extends to about 12 km (as is observed), with radiative equilibrium above 12 km (as is observed), does the atmosphere satisfy the conditions of dynamic stability and thermal equilibrium with the received solar energy. For this case the calculated sea-level temperature is 290°K in good agreement with the observed value 287° K.

Calculation shows that doubling or tripling the amount of the carbon dioxide of the atmosphere increases the average sea-level temperature by about 4° and 7° K respectively; halving or reducing to zero the carbon dioxide decreases the temperature by similar amounts. Such changes in temperature are about the same as those which occur when the Earth passes from an ice age to a warm age, or *vice versa.* Thus the calculation indicates that the carbon-dioxide theory of the ice ages, originally proposed by Tyndall [Phil. Mag., **22,** 277 (1861)], is a possible theory. (*Author's abstract.*)

Discussed by Messrs. WHITE, L. H. ADAMS, HUMPHREYS, CURTIS, and HAWKESWORTH.

O. R. WULF: *The ozone distribution and the temperature of the upper atmosphere.*—Experimental evidence and theory combine to indicate that the ozone of the upper atmosphere is distributed as a fairly sharply defined layer, and that this is located at a height of roughly 50 kilometers. In work done recently at the Fixed Nitrogen Research Laboratory by Dr. E. H. Melvin and the author an influence of temperature has been found in the ultraviolet absorption bands of ozone. In view of the above, a method is proposed for the direct determination of the temperature of the upper atmosphere at the height of the ozone layer. This comprises a photometric comparison of the atmospheric ultraviolet ozone absorption in the spectra of stars giving a satisfactory continuous background in this region, with the same ozone absorption spectra taken at a series of temperatures in the laboratory. (*Author's abstract.*)

Discussed by Messrs. HULBERT and HUMPHREYS.

An informal communication was presented by A. H. SCOTT on *Dielectric constant and power factor of fused zinc oxide.*

## 1031ST MEETING

The 1031st meeting was held in the Cosmos Club Auditorium, Saturday evening, January 16, 1932. It was called to order at 8:30 P.M. by President TUCKERMAN.

*Program:* H. L. CURTIS: *The determination of the electrical units by mechanical measurements.* This paper has been printed in full in the pages of this JOURNAL (**22:** 193).

## 1032D MEETING

The 1032nd meeting was held in the Cosmos Club Auditorium, Saturday evening, January 30, 1932. The meeting was called to order at 8:15 P.M. by President TUCKERMAN.

*Program:* F. L. MOHLER: *Temperature variations of the absorption of metallic silver.*—Published work has shown that the sharp transmission band of silver with its maximum at 3200 AU changes with temperature. A quantitative study of this has been made by the method of photographic densitometry over the temperature range 220°C to −253°C (boiling hydrogen). The quantity measured is

$$\log J_o - \log J = a$$

where $J_o$ is the incident intensity and $J$ the transmitted intensity and values are given in common logarithms. For films of chemically deposited silver and of silver evaporated in vacuum and for films of different thickness, the change in $a$ between fixed temperatures remains proportional to $a$. The change is limited to the wave-length range 3400 AU to 2900 AU with the maximum effect near 3100 AU. The short wave-length branch of the absorption curve becomes less steep with increasing temperature and the minimum less pronounced while the long wave-length branch is unchanged. For one specimen the value of $a$ at −253°C was 0.4; at 220°C, 1.2 at 3100 AU. The change in $a$ remains nearly proportional to the temperature change. (*Author's abstract.*)

Discussed by Messrs. BRICKWEDDE and TUCKERMAN.

F. G. BRICKWEDDE: *A hydrogen isotope of mass 2 and its concentration.*—Last summer Birge and Menzel suggested the possible existence of an isotope of hydrogen with mass number two ($H^2$) to explain the difference between the atomic weights of hydrogen as determined chemically and by Aston using the mass spectrograph when reduced to a common basis. Isotopes of hydrogen with mass numbers two and three and helium five are needed to give regular arrangements of atomic nuclei a completed appearance when extrapolated to smallest atomic weights.

A calculation of the vapor pressures of pure isotopic crystals of the different molecular species $H^1H^1$, $H^1H^2$, $H^1H^3$ yield values of the vapor pressure which are in the ratio of 1:0.37:0.30 at 14°K, the triple point for ordinary hydrogen. Although a calculation for the liquid state was not possible it did seem reasonable to believe that heavier isotopic molecules if present should be rapidly concentrated in a residue of liquid hydrogen evaporated at the triple point. Samples of hydrogen were prepared in the Cryogenic Laboratory of the Bureau of Standards from the residue of four to six liters of liquid evaporated at the normal boiling point and triple point. These samples were examined with a grating spectrograph by Prof. Harold C. Urey and Dr. G. M. Murphy at Columbia University for the visible atomic Balmer Series lines of hydrogen atoms with masses two and three, the wave-lengths of the new lines being calculated in advance of the measurements. It was found that the known lines $H\alpha$, $H\beta$, $H\gamma$, and $H\delta$ are accompanied on the short wave-length side by weak lines agreeing within experimental error (about 0.02AU) with the calculated wave-lengths for an isotope of mass two, the corresponding $H^1$ and $H^2$ lines differing in wave-length by between 1 and 2 AU. The $H^2\alpha$ line was resolved into a doublet with a separation agreeing with that for the known $H^1\alpha$ line. The isotopic lines are not as diffuse as the known $H^1$ lines, probably due to a smaller Doppler broadening. The isotopic lines

were found in ordinary hydrogen with an intensity of about 1/4000th the intensity of the $H^1$ lines, which yields a value for the ratio of $H^2$ to $H^1$ atoms in ordinary hydrogen of 1 to 4000.

The sample prepared from six liters of liquid by evaporation at the normal boiling point showed no increase in the concentration of the isotope, indicating that the vapor pressures of the pure isotopic liquids at 20°K are the same. In one sample prepared from four liters of liquid hydrogen evaporated at the triple point the concentration of the isotope was increased about 700 per cent. These increases in concentration which are larger than have been attained before for any isotope made possible the positive identification of the isotope.

No evidence for $H^3$ was found. (*Author's abstract.*)

Discussed by Messrs. UREY, MOHLER, HAWKESWORTH, GISH, BLAKE, CRITTENDEN, CURTIS, GIBSON, and TUCKERMAN.

### 1033D MEETING

The 1033rd meeting was held in the Cosmos Club Auditorium, Saturday evening, February 13, 1932. The meeting was called to order at 8:15 P.M. by President TUCKERMAN.

*Program:* Ross GUNN: *The evolutionary origin of the solar system.*—A new account for the formation of the solar system, based on the rotational evolution of a single parent star, is given which describes the system in some detail and avoids the major difficulties encountered by earlier investigators. Electric and magnetic forces acting on the ions of a star's atmosphere determine its motion and stability, and permit the angular velocity of the star to increase until the star breaks into two component stars of comparable mass. The hot face of each component star which has just emerged from the deep interior of the parent star loses momentum by radiation more rapidly than the cool face and kinetic energy and angular momentum are added to the star pair in such a way as to form a stable binary system. It seems probable that the mechanism will separate the stellar components to infinity in a great many cases and two single stars produced. Applying this to the solar system the Sun is supposed to have divided and lost its companion. While each component star was inside the Roche limit of the other, centrifugal and tidal forces broke off the planets. These in turn broke up for the same reason and produced the planetary satellites. Tides and tidal couples transferred the momentum of axial spin of the two component stars to that of orbital momentum, leaving the Sun rotating very slowly. The planets, because of their small size, largely escaped this process and originally rotated on their axes with a period approximating the critical period of the parent star. The birth of the Moon and its relative size compared to the Earth is well explained by the theory. The account replaces the earlier improbable and "accidental" theory by a systematic evolutionary process that may be quite common in the universe. (*Author's abstract.*)

Discussed by Messrs. WHITE, HECK, HUMPHREYS, HAZARD, CURTIS, L. H. ADAMS, STIMPSON, and TUCKERMAN.

L. H. ADAMS: *The solidification of the earth.*

Discussed by Messrs. HAWKESWORTH, WHITE, HECK, CURTIS, HUMPHREYS, GIBSON, and TUCKERMAN.

### 1034TH MEETING

The 1034th meeting was held in the Cosmos Club Auditorium, Saturday evening, February 27, 1932. The meeting was called to order at 8:20 P.M. by Vice President O. S. ADAMS.

*Program:* R. J. SEEGER: *The growth of the electron concept in physics.* Discussed by Messrs. CURTIS, HEYL, and GIBSON.

D. L. WATSON: *Biological organization as a physico-chemical problem.*—G. N. Lewis has said that "living creatures are cheats in the game of physics and chemistry." From the standpoint of physics the problem of biological organization is to determine statistically, what is the nature of this cheating.

Organization, in an otherwise random system, can be discerned by (*a*) it strikes the attention of the observer and makes the distribution of the parts easier to apprehend; (*b*) its nature implies some specific *purpose* for which the system may be used. Entropy, as a measure of physical organization, does not aid in the analysis of complex structures such as used in physical research, engineering or living matter. It applies only to simpler, quasi-isotropic systems and measures only the special kind of organization whose purpose is to perform work on outside systems.

The classical meaning of entropy arises through the Boltzmann formula and therefore through the probability concept. The probability of a state, however, is a function of the method of classification applied to the system and therefore of the means available for observing the possible configurations. Thus the subjective aspect of our apprehension of organization (mentioned above) can, in the cases in which we are interested, influence the value of the probability and (in a sense) the value of something-corresponding-to-the-entropy. This conclusion is implied in the recent work of G. N. Lewis and P. W. Bridgman. From this point of view, the Second Law requires merely that changes take place from easily classified states to less easily classified states. If entropy measures only one kind of organization, an extension of the entropy concept or a new measure of organization is necessary for biology.

Organization of biological systems is produced by key structures which we can call "selecting mechanisms." These produce a steady warping of the statistics of the assembly in which they occur. New classifications, unfamiliar in theoretical physics, are more readily adapted to these "warped" configurations, and this is the nature of the "cheating" to which Lewis refers. Such selecting mechanisms can appear spontaneously under suitable physical and chemical conditions. Intelligence is not necessary. In any case, mechanical selecting devices having more and more of the characteristics of intelligent beings are becoming commoner, both in engineering and experimental psychology. (*Author's abstract.*)

Discussed by Mr. GIBSON.

*Informal communication:* W. J. HUMPHREYS: *The colder the air the thinner the ice.*—It is a saying among certain Great Lakes fishermen that ice grows faster in zero (Fahrenheit) weather than it does when the temperature is considerably subzero. This, if true, is one of nature's many paradoxes, one of her pleasing puzzles which it always is a delight to solve. But is it true?

Evidently the rate of thickening of the ice (at the under surface of course) is proportional to the rate of loss of heat by the water up through the ice cover. Under steady conditions this rate in turn is proportional directly to the thermal conductivity of the ice and the difference in temperature between its upper and under surfaces, and indirectly to the thickness of the ice sheet. In other words, it is proportional to the conductivity of the ice and the temperature gradient through it. Now the conductivity of ice is a constant, nearly, if we neglect, or take into account and average, the effect of air bubbles and other irregularities. Also the temperature at the under surface of the ice is a constant, namely, 32°F. in the case of fresh water. We, therefore, can say that for any given thickness of the ice, the rate of its further

growth, under steady conditions, is directly proportional to the extent to which the temperature of its outer surface is below the freezing point. That is, it is proportional to $32 - t_s$, in which $t_s$ is the temperature, as indicated by a Fahrenheit thermometer, of the upper surface. If, then, this upper surface always had the temperature of the air above it, there would be no occasion to explain the paradox in question for there would be no paradox. But this relation does not always hold and in that fact we have the solution of our fisherman's puzzle.

At temperatures around zero Fahrenheit there is not likely to be much fog drifting over the ice from the open water farther out in the lake, and often too at such times there is wind enough to keep the surface of the ice swept clean of snow. On the other hand, when the temperature of the air is considerably lower the "frost smoke," produced by the "steaming" of the open, deep water and remaining unevaporated at the low temperature, well may spread out slowly over the ice and thereby not only decrease the net loss of heat by radiation, as fogs and clouds always do by the return radiation they themselves give out, but also decrease it, sometimes very greatly, by depositing over the ice an insulating sheet of finely powdered snow. Any substance, even a metal, when finely divided, is a poor conductor of heat, and snow is one of the poorest. Hence ice covered with a layer of fine snow, even though that layer be very thin, loses heat to colder air above much more slowly than it would if bare. Obviously, therefore, under otherwise like conditions ice increases in thickness much faster when bare than it does when snow covered.

Ice of any given thickness grows fastest when its surface is coldest; but this temperature depends in part on the condition of the air above—clear, cloudy, or foggy—and on the condition of its surface, clean or snow covered. And the fog blanket and the fine snow cover are most likely to form in relatively calm and very cold weather, drifted by the gentle movement of the air that commonly obtains on such occasions over and onto the ice sheet to the leeward of the remaining open water.

It well may be, therefore, as fishermen tell us, that at certain places, at least, along the shores of the Great Lakes, more ice is formed occasionally, perhaps also on the average, when the temperature of the air is around zero Fahrenheit than there is when that temperature is even 20° to 30° lower, owing, as explained, to the greater prevalence of clear air and clean ice in the first case and foggy air and snowy ice in the second.

But here also, as everywhere and always, a few appropriate figures afford a very necessary check on one's general or qualitative reasoning. Let the conditions be:

*a*. Temperature of the air −18°C., 0°F., approximately,
Thickness of ice, 5, 10, 25, 50 centimeters, respectively.
Snow covering, none.

*b*. Temperature of the air −29°C., −20°F., roughly.
Thickness of ice, as in cases *a*.
Snow covering, 1 millimeter.

*c*. Same as *b* in respect to temperature of air and thickness of ice.
Snow covering, 5 millimeters.

Now since the radiations of snow and ice at these low temperatures are small; the reflection of sunlight and skylight by snow roughly 90 per cent; the amount of such radiation absorbed by ice also small, especially since there is not likely to be much of it to absorb in mid-winter at latitude 47° N., say; and the heat conductivity of ice very low, therefore, as a first approxima-

tion, we may assume the temperature of the top surface of the snow, or bare ice, to be that of the adjacent air. The temperature of the under surface of the ice is, of course, 0°C. Furthermore, as experiment has shown, the conductivity of very loose snow may be as low as one three-hundredth that of ice. Assume it, in the present case, to be one one-hundredth that value, so that, as a heat insulator, a layer of our fine snow one millimeter deep is the equivalent of a sheet of ice 100 times as thick—10 centimeters; a 5 millimeter covering of snow the equivalent of a 50 centimeter sheet of ice; and so on for other depths and thicknesses.

In case *a* the difference in temperature between the under and upper surfaces of the ice is 18°C., and in cases *b* and *c* the difference between the temperature of the under surface of the ice and top surface of the snow 29°C. Therefore our various temperature gradients, in terms of centigrade degrees and thicknesses, or equivalent thicknesses, in centimeters, of ice are as given in the following table.

*Temperature Gradients*

| Thickness of ice, cm. | 5 | 10 | 25 | 50 |
|---|---|---|---|---|
| Bare<br>Air −18°C. | $\frac{18}{5}$ | $\frac{18}{10}$ | $\frac{18}{25}$ | $\frac{18}{50}$ |
| 1 mm. snow<br>Air −29°C. | $\frac{29}{15}$ | $\frac{29}{20}$ | $\frac{29}{35}$ | $\frac{29}{60}$ |
| 5 mm. snow<br>Air −29°C. | $\frac{29}{55}$ | $\frac{29}{60}$ | $\frac{29}{75}$ | $\frac{29}{100}$ |

From these gradients it is clear that often bare ice can grow faster when the temperature of the air is 0°F. than can snow covered ice of the same thickness when the air is much colder, even −20°F. When the thickness of the ice is 16.3 centimeters (6.4 inches) it grows just as fast in 0°F. weather, if bare, as it would with a 1 mm. covering of loose snow (conductivity of snow one one-hundredth that of ice) in weather at −20°F. If thinner, the bare ice would grow faster than the snow covered at the given temperatures, and if thicker it would grow slower. If the depth of the snow were 5 mm. the thickness of the ice would need to be 81.8 centimeters (32.2 inches) for the rates of growth, under the given conditions, to be the same.

In the first of these cases the rate of increase of thickness is about one centimeter in 4 hours, the conductivity of ice being 0.005 (transmitting 0.005 calorie per second per square centimeter cross-section when the temperature gradient is 1°C. per centimeter), and in the second case one centimeter in 20 hours.

Thus the fisherman's interesting paradox, the colder the air the thinner the ice, has become orthodox and lost its fascination. (*Author's abstract.*)

### 1035TH MEETING

The 1035th meeting was held in the Cosmos Club Auditorium, Saturday evening, March 12, 1932. The meeting was called to order at 8:18 P.M. by President TUCKERMAN.

*Program:* F. K. HARRIS: *Application of the cathode-ray oscillograph.*—The sensitivity of cathode-ray oscillographs and the upper limit of their range

of usefulness in high-frequency recording were discussed. The application of the oscillograph to the investigations of transmission-line transients initiated by lightning, and the use of the oscillograph as a recording wattmeter were discussed in some detail. (*Author's abstract.*)

Discussed by Messrs. WENNER, GISH, CURTIS, and HUMPHREYS.

P. R. HEYL: *Cause or chance?* The past third of a century has called into question and modified or discarded most of the theoretical principles of physical science which had formerly been regarded as permanently established. It has been reserved for the last few years to attack what has always been regarded as the most fundamental principle of all, for there has come a change in the scientific attitude toward the law of cause and effect. This latest skepticism concerns itself principally with the behavior of electrons. The new philosophy asserts that the future course of an electron is a matter not for definite prediction, but only of statistical probability.

There is an imposing array of authority on the side of this new and strange doctrine—Bohr, Heisenberg, Dirac, Jordan, Born, Eddington, and others, while the opposition can name but one physicist of the same rank—Planck.

Those who have adopted this position have done so because of the increasing difficulty of giving a satisfactory explanation of electronic phenomena in terms of the classical frame of space-time. It appears that a probability-interpretation of the equations of wave mechanics avoids all the present difficulties. On this interpretation, causal laws are replaced by laws of probability. (*Author's abstract.*)

Discussed by Messrs. BRICKWEDDE, HORST, HUMPHREYS, and LITTLEHALES.

*Informal communications:* P. R. HEYL described a method of testing character of knife-edges by a balance method.

Discussed by Messrs. WENSEL, LITTLEHALES, WHITE, and HUMPHREYS.

H. L. CURTIS described a mechanical wave filter for low frequencies.

## 1036TH MEETING

The 1036th meeting was held in the Cosmos Club Auditorium, Saturday evening, March 26, 1932. The meeting was called to order at 8:15 P.M. by President TUCKERMAN.

*Program:* J. E. IVES: *The physicist in public health work.*—The important part played in preventive medicine, and particularly in industrial hygiene, by the physicist, was emphasized. Medicine is interested in the relation of man to his physical environment; to radiation, to the temperature, humidity, velocity, and ionization of the air, and to the dust-content of the air. The physician determines the intracorporeal quantities such as blood pressure, body temperature, pulse rate, etc., while the physicist determines the extracorporeal quantities, such as temperature and velocity of the air, and intensity of radiation (ultraviolet, visible, and infrared).

In industrial hygiene, the illumination, both natural and artificial, of workshops is of importance, involving the size and location of windows, and the location of lighting units. Certain intensities of lighting are necessary to protect the eye, and to promote industrial efficiency.

Ventilation of shops and factories is also of importance from the hygienic point of view.

In private dwellings, spacing, lighting and air-conditioning call for the knowledge of the physicist as well as that of the physician. The best size of room, and height of ceiling, involve problems both for the physiologist and the physicist.

Radiation has many problems in which both the physicist and the physi-

cian are interested, such as the properties of therapeutic lamps, the transmission of ultraviolet rays by window glass, radiation of infrared rays from molten iron and glass, and of the less intense infrared radiation from the ceilings and walls of houses and schoolrooms, and the effect of these radiations upon the body and the eyes. (*Author's abstract.*)

Discussed by Messrs. TUCKERMAN, RAMBERG, HAWKESWORTH, BLAKE, and HECK.

F. S. BRACKETT: *The division of radiation and organisms of the Smithsonian Institution.*

Discussed by Dr. IVES.

*Informal communication:* R. B. KENNARD described an apparatus for measuring small pressure-differences and small velocities of a gas. The apparatus consisted essentially of a manometer with means provided for making accurate readings. The apparatus was placed on exhibition before the Society.

### 1037TH MEETING

The 1037th meeting was held in the Cosmos Club Auditorium, Saturday evening, April 9, 1932. The meeting was called to order at 8:15 P.M. by President TUCKERMAN.

*Program:* R. B. KENNARD.—*The interferometer as an instrument for measuring air temperatures near heated surfaces.*

Discussed by Messrs. WHITE, TUCKERMAN, and WENSEL.

WM. F. ROESER: *Reference curves for use with thermocouples.*—Reference tables for thermocouples give a relation between electromotive force and temperature. These tables in conjunction with suitable deviation curves, serve as a convenient means of interpolating between calibration points and converting readings of electromotive force to temperature.

It has been found advisable to revise the classic table prepared by Adams for the standard platinum to platinum-10% rhodium thermocouple to make it conform to the present temperature scale. Careful study of ten representative couples, moreover, indicated that the thermocouples of this type used today do not have exactly the same characteristics as those upon which Adams' table was based. The principal change made in Adams' table for platinum to platinum-10% rhodium thermocouples was at temperatures above the gold point (1063°C). The maximum change below 1200°C was 0.5°C, whereas the change at 1500°C was 4°C.

New tables were also prepared for platinum to platinum-13% rhodium thermocouples and for several couples of base-metal alloys. (*Author's abstract.*)

Discussed by Messrs. L. H. ADAMS and WHITE.

*Informal communication:* W. P. WHITE discussed his experiences and difficulties in calibrating thermocouples.

Discussed by Messrs. ROESER and WENSEL.

C. GOLDENBERG described and gave an explanation of two smoke puffs from large guns.

### 1038TH MEETING

The 1038th meeting was held in the Cosmos Club Auditorium, Saturday evening, April 23, 1932. The meeting was called to order at 8:30 P.M. by President TUCKERMAN.

*Program*: Prof. A. E. KENNELLY: *The work of Joseph Henry in relation to applied science and engineering.* The Joseph Henry lecture, published in this JOURNAL **22**: 293.

### 1039TH MEETING

The 1039th meeting was held in the Cosmos Club Auditorium, Saturday evening, May 7, 1932. The meeting was called to order at 8:15 P.M. by President TUCKERMAN.

*Program:* RICHARD COURANT: *Alternating electric currents in the earth and their application.*

Discussed by Messrs. HAWKESWORTH, GISH, RAMBERG, GIBSON, DANTZIG, and TUCKERMAN.

*Informal communication:* O. H. GISH reported upon the phenomenon of earth-currents flowing consistently upward towards the top of hills and mountains. An explanation for this phenomenon was suggested based upon systematic differences in hydrogen-ion concentration between the top and bottom of the hills and mountains.

### 1040TH MEETING

The 1040th meeting was held in the Cosmos Club Auditorium, Saturday evening, May 21, 1932. The meeting was called to order at 8:15 P.M. by President TUCKERMAN.

The proposed changes in by-laws, recommended at a special business meeting of the General Committee called by the President on May 5, were voted upon at this meeting and adopted as follows:

Article I, Sec. 6, after "Treasurer," first line, insert "or in his absence or inability to act, the Acting Treasurer provided for in Article I, Sec. 7."

Add, Article I, Sec. 7, "The general Committee shall have power to designate any one of its members except the President, a Vice-President or a Secretary as Acting Treasurer to serve during the absence of the Treasurer or his inability to act."

The purpose of the above amendments is to make it possible, especially during the present depression, for changes to be made in the Society's investments in case of an emergency during the absence or illness of the Treasurer, who now is the only person having access to the Society's securities.

*Program:* H. H. KIMBALL: *Solar radiation as a meteorological factor.*— Variations in the Earth's solar distance cause variations in the intensity of solar radiation at the outer limit of the Earth's atmosphere of very nearly 3.5 per cent on each side of the mean, with the maximum early in January and the minimum early in July.

Variations in solar declination cause seasonal variations in the daily totals of solar radiation as measured at the surface of the Earth, which are small at the equator, but increase rapidly with latitude. At Havana, Cuba, latitude 23° 09′N., the average daily amount at the time of the summer solstice is about double that at the time of the winter solstice; at Washington, D. C., latitude 38° 56′N., the corresponding ratio is about 3.5; at Stockholm, Sweden, latitude 59° 21′N., it is about 20, and at Sloutzk, U.S.S.R., about 40.

Following explosive volcanic eruptions the great quantity of dust thrown into the atmosphere, some of it to great heights, has diminished the intensity of the direct rays of the Sun as received at the Earth's surface from 15 to 25 per cent for periods of several months. Such explosions, with their accompanying dust-clouds, occurred in 1883, 1888–1891, 1902, and 1912, and a slight cooling of the Earth as a whole seems to have followed. On the other hand, there have been no such eruptions since 1912, or during a period of nearly 20 years, and Angström is of the opinion that on account of the small amount of dust now present in the stratosphere the temperature of the Earth should be slightly higher than usual.

For solar constant values it has been claimed that periodicities of from 68 to 8 months exist, with amplitudes of from 0.005 to 0.014 calories, or about 0.3 to 0.7 per cent of the mean value. Also, that there are short-period trends in values, with an average length of 5 days and an average amplitude of 0.8 per cent. To these short-period trends of less than one per cent in magnitude, have been attributed the *major changes in weather.*

A careful study of these various variations in the intensity of solar radiation leads to the conclusion that weather changes are brought about, not by short-period trends of less than one per cent, but by the many-fold difference in the intensity of the solar radiation received by the Earth in equatorial and polar regions. As a result great temperature differences exist between these regions. Gravity causes the heavy cold air to displace the lighter warm air at the surface, and a polar-equatorial circulation is set up, turbulent in character, especially in winter when the temperature difference is most marked. Well-defined movements of this character are to be found on the weather maps of the different countries, and examples are shown in this paper in reproductions of weather maps for the United States. It is to studies of this turbulent polar-equator movement of air that meteorologists look for improvements in weather forecasting, and it is for such studies that the meteorological work of the *Jubilee International Polar Year 1932–1933* is now being organized.

As stated by the Chairman of the Commission for the Polar Year, "The further that extensions have been made of the dynamical theories of air interaction in moderate latitudes for practical forecasting purposes, the clearer has it become that atmospheric processes in the polar regions of both hemispheres play a predominant part. These regions are very often the source of the surges in the atmosphere whose necessary outcome are the weather variations at low latitudes. An intimate study, therefore, of the behavior of the atmosphere in high latitudes has now become a necessity for the extension in knowledge of weather processes." (*Author's abstract.*)

Discussed by MERWIN, CURTIS, HUMPHREYS, LITTLEHALES, GIBSON, and HAZARD.

W. J. HUMPHREYS: *If Greenland's ice should melt.*—If all the ice on Greenland should melt, so also would the ice on Antarctica and every part of the world. From recent depth soundings of this ice, and from other evidence, it seems that the melting of it all would raise the level of the oceans about 150 feet. This would be a calamity of the highest order, since it would mean the abandonment of many great cities and much rich coastal land. Furthermore, the melting of the ice would cause profound climatic changes. Storms then, owing to the relatively small temperature contrast between poles and equator, would be few and feeble, and mainly pass at much higher latitudes than they now do. Hence all mid-latitude regions would then be semi-arid to desert.

This disastrous condition, which appears to have been the world's normal state through much the greater part of its history, may again be upon us in only a few thousand years, and will be if the ice continues to melt in the future as, on the average, it has melted since the maximum advance of the last glacial sheets, some 30,000 years ago. Of course, the retreat of the ice may cease at any time and a greater or less advance begin. That often has happened, and an advance could now be started by certain minor geologic changes.

Presumably a number of suitably installed and properly located gages would soon tell us definitely how fast the oceans are filling up; how rapidly, therefore, the ice is melting, and how swiftly the world is passing into its customary semi-arid and more or less desolate state. (*Author's abstract.*)

Discussed by Messrs. LITTLEHALES, TUCKERMAN, CURTIS, DRYDEN, and WRIGHT.

G. R. WAIT, *Recording Secretary.*